LETIN 85 BURIED OYSTER SHELL RESOURCE

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BURIED OYSTER SHELL RESOURCE EVALUATION OF THE EASTERN REGION OF THE ALBEMARLE SOUND

NORTH CAROLINA
DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES
DIVISION OF EARTH RESOURCES
GEOLOGY AND MINERAL RESOURCES SECTION

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1976

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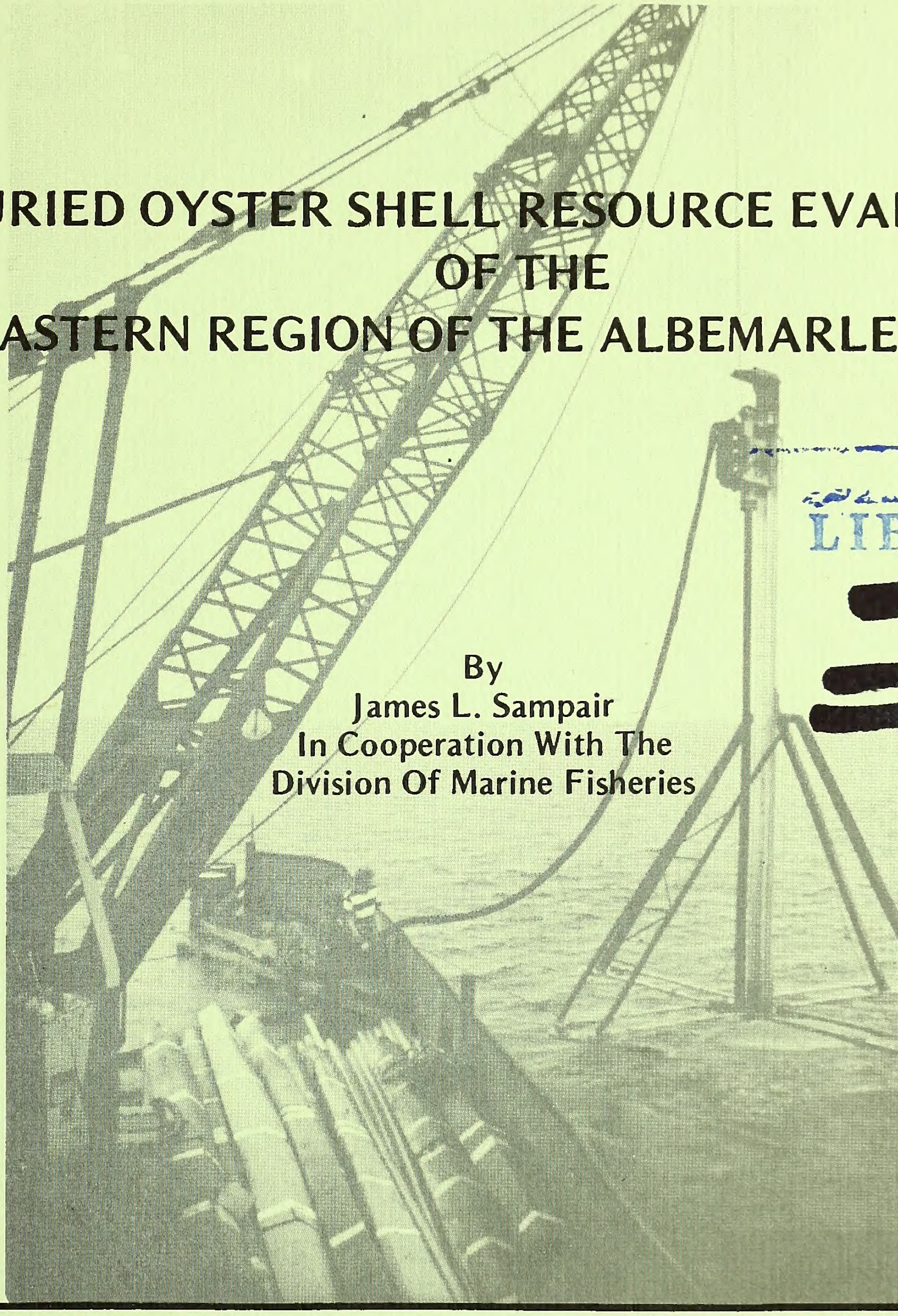

By
James L. Sampair
In Cooperation With The
Division Of Marine Fisheries

NORTH CAROLINA
DEPARTMENT OF NATURAL AND ECONOMIC RESOURCES
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GEOLOGY AND MINERAL RESOURCES SECTION

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1976

COVER PHOTOGRAPH SHOWS ALPINE "VIBRA CORE" BEING LOWERED INTO THE ALBEMARLE SOUND BY MEANS OF A BARGE-MOUNTED CRANE.

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OF THE

EASTERN REGION OF THE ALBEMARLE SOUND

BY

JAMES L. SAMPAIR

IN COOPERATION WITH THE

DIVISION OF MARINE FISHERIES

GEOLOGY AND MINERAL RESOURCES SECTION

This section shall, by law ". . .make such examination, survey, and mapping of the geology, mineralogy, and topography of the state, including their industrial and economic utilization, as it may consider necessary.

In carrying out its duties under this law, the section promotes the wise conservation and use of mineral resources by industry, commerce, agriculture, and other governmental agencies for the general welfare of the citizens of North Carolina.

The Section conducts a number of basic and applied research projects in environmental resource planning, mineral resource exploration, mineral statistics, and systematic geologic mapping. Services constitute a major portion of the Section's activities and include identifying rock and mineral samples submitted by the citizens of the state and providing consulting services and specially prepared reports to other agencies that require geological information.

The Geology and Mineral Resources Section publishes results of its research in its own series of Bulletins, Economic Papers, Information Circulars, Educational Series, Geologic Maps, and Special Publications. For a complete list of publications or more information about the Section please write: Geology and Mineral Resources Section, P. O. Box 27687, Raleigh, North Carolina 27611.

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BURIED OYSTER SHELL RESOURCE EVALUATION OF THE EASTERN REGION OF THE ALBEMARLE SOUND

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ABSTRACT

Two hundred and sixty three miles of subbottom profiling were done in the lower Albemarle Sound, Roanoke Sound, and Croatan Sound using a Raytheon RTT 1000, 3.5 Khz "pinger". This was followed by a core program using an Alpine Geophysical 20 foot "Vibra Core". Sixty cores were taken at tie points and on sedimentary structures indicated by the geophysical profiles.

Three broad areas of interest were defined for the presence of buried shell deposits, and nine prospects are indicated on maps attached to this report. The bathymetry, the overburden thickness, and the shell unit thickness are also indicated on the maps. Five permanent files were set up in the Geology and Mineral Resources Section: one containing color slides of the cores taken, one containing strip logs of the cores (consisting of color photographs with written lithologic descriptions), one consisting of a sample file containing five cuts each of all of the cores, one containing the geophysical profiles, and one containing a computerized file of navigation data. There is also a 10 minute, 16mm film of the various elements of the field operation on file with the Division of Marine Fisheries.

As a result of this study, we estimate a potential for 30.6 million cubic yards of oyster shell in the study area, with a current raw material market value in excess of $90,000,000.00. A one-dredge operation would take a little over 20 years to extract these shells and would employ 90 people year around at an average annual payroll of $900,000.00.

PURPOSE AND SCOPE

This study is the first step in a program of the Department of Natural and Economic Resources to locate and map the calcium carbonate shell deposits in the bays, estuaries, and sounds of eastern North Carolina. It is a principle objective of this program that both the environmental and the economic impacts of utilizing the shell resources be understood. The area covered by this study includes lower Albemarle, Croatan, and parts of Roanoke Sounds (see Plate 1).

The study developed suitable techniques for accurately locating shell reefs and associated sediments by rapid reconnaissance of large marine areas at reasonable costs. A subsurface coring method was developed for sampling and measurement of the shell deposits located during reconnaissance.

Data on thickness and type of overburden, thickness and type of shell and matrix material, and lithology and sequence of the associated sedimentary sections were derived from the field techniques utilized in this study. Data on sedimentary mineralogy, stratigraphy, sedimentary structure, and paleontology are available from photo strip logs of the cores, color slides of the cores, cuts of the actual core material, and seismic profiles. These materials are on file with the Geology and Mineral Resources Section and can be used to support future geologic studies and mineral resource evaluations as well as water-use planning studies. All data collection points are precisely located by range-range data and by Carter Coordinate data which have been computerized.

In addition to indicating the location of the shell deposits encountered in coring, this report provides thickness maps of both the oyster shell and overburden and a discussion of the materials, geology, and possible environmental impacts.

ORGANIZATION AND ACKNOWLEDGEMENTS

The contractor for this project was the Department of Natural and Economic Resources. The Division of Earth Resources and the Division of Marine Fisheries of this Department were assigned the task of executing the contract. Mr. Stephen G. Conrad, Director of the Division of Earth Resources, had primary responsibility for organization and administration of the project.

The author, Geologist-in-Charge of the Coastal Plains area for the Geology and Mineral Resources Section of the Division of Earth Resources, and Mr. James Brown, Assistant Director for Marine Fisheries, were given responsibility for the execution of the necessary studies and for reporting the results.

There are many people whose efforts resulted in the timely completion of this project. The author would like especially to thank Loi Priddy with Marine Fisheries who was a "jack of all trades" in the project, in particular for his work in surveying, navigation, and computer technology; Orvill Tillet of the Enforcement Division of Marine Fisheries was our very able boat captain during the geophysical survey and also helped us whenever he could during the coring operation; Jim Tew and Fentress Mundane of Marine Fisheries found it necessary at times to revise their plans and schedules in enforcement and oyster rehabilitation in order to make people and equipment available to this project; and Jim Coffey,

staff geologist in the Coastal Plains area, did the photography on the cores and prepared many of the illustrations and maps for this report. There are others in Marine Fisheries and in Earth Resources who made substantial contributions to the drafting, manuscript, and budget management whom we would also like to thank for their time and effort.

FIELD WORK

The field work was accomplished in two steps. A reconnaissance reflection seismic survey of the study area and shallow coring aided in correlation of the seismic data and in testing specific anomalies noted on the seismic profiles which were thought to be prospective shell deposits. The volume of coring was limited by budget constraints but was sufficient to prove the method.

Subbottom Profiling

The principle constraints in deriving specifications for this part of the project were cost per unit coverage, speed, and depth of investigation. A shallow-survey reflection seismic system seemed to be suited for the purpose and the following systems were investigated: the E.E.G. Uniboom, the Edo Western 7 and 3.5 Khz Transducers, and the Raytheon 3.5 Khz Transducer.

Due to the 10-foot average depth of the water, the cost of equipment, and the non-critical penetration requirement, the Uniboom was not considered in detail. Because of the water depth and the unconsolidated nature of the sediments to be investigated, the low frequency 3.5 Khz transducer unit was selected as the optimum tool. Raytheon was low bidder on this equipment. Special mounting equipment was designed by the author and Loi Priddy of Marine Fisheries so that the equipment could be installed on an eighteen-foot boat furnished by James Tew, Chief of Enforcement of Marine Fisheries.

Navigation was the next concern. It is essential that sites from which data is acquired be located sufficiently well so that they can be easily relocated for future work. Degree of accuracy, cost, power requirements, ease of installation, and effective operational range were all considerations. Costs and timely availability varied widely for this equipment. The Motorola Mini-Ranger system with an Anadex paper tape recorder was selected on the basis of cost and service. This system served very faithfully with an accuracy of ±10 feet out to distances of twelve miles from shore stations. Had we also included a punch tape recorder, a savings in time and money could have been effected in the subsequent computerization of the navigation data. The author was not aware early in the planning of this project that a "Cal Comp" plotter would be part of the computer hardware available to the program from

North Carolina State University. Because of budget limitations, we had only considered hand plotting the data. In order to make use of the "Cal Comp" plotter, the data from the Anadex recorder had to be key punched. Loi Priddy and Dr. David Link of the Computer Science Department at NCSU developed the program to convert the range-range data from the Anadex recorder to the Carter x-y coordinate system and plot the boat tracks using the "Cal Comp" plotter.

The activities and location data printed on the maps (in pocket) included in this report display the seismic survey network as plotted by "Cal Comp" plotter. One can see in reviewing the network that an automatic pilot on the boat would have also been of considerable assistance.

The seismic equipment emits a signal at a frequency of 3.5 Khz. On the Raytheon equipment, the impulse rate, strength, and phase are adjustable in the hope that the operator may find the combination that best defines the sedimentary section and achieves the most satisfactory penetration. The impulses are reflected from velocity interfaces starting with the water-bottom contact and are received by the transducer in a recording mode. These signals are transmitted to a Raytheon recorder which is typical of their research fathometer unit.

In very shallow water, a multiple reflection of the water-bottom contact appears on the record at a depth below the contact equal to the water depth. Unfortunately, in this situation, the multiple appears in the portion of the record that is of greatest interest to this study. Adjusting the instruments for signal strength and timing minimizes this problem but does not eliminate it.

The results achieved from the reconnaissance survey vary from poor to very good. In part, the variation was due to the operator's improving technique as he gained experience with the equipment and in part to water depth and sediment type. A total of 263 profile miles of seismic lines, represented by the boat tracks printed on the maps (in pocket), were achieved at an approximate cost of $40.00 per profile mile.

A preliminary review of the data was carried out to determine the best possible location for our core sampling program. We determined that in addition to coring some sedimentary structures that appeared to be shell deposits, we would need coring to tie the intersections of our seismic profiles to determine reasonable sedimentary correlations. The lateral sedimentary facies relationships are extremely complex.

Two important constraints entered into consideration of a coring technique for this study. First, the budget was extremely limited for this sort of work which is quite expensive to do even on land. Second, we presumed that dredging, because of the environmental hazards, would be limited to depths of thirty feet or less. The author realizes there may be considerable controversy on this point; however, such a limitation would have been necessary in any event in order to get any appreciable tie data for the seismic data, given the budget constraints.

There are basically only two ways this coring could be done. The first method would be to employ a drilling machine equipped with core barrels mounted on a barge that could be anchored in a very stable manner both horizontally and vertically. Because of the mobility of the water and the penchant for the winds and weather to change drastically over very short periods of time (15 to 20 minutes on occasion), this method is very costly in relation to the amount of coring that can be accomplished. A second method of coring is to drive coring tubes with a hammer using a barge as a platform. Among the specific methods for doing this is a device developed by Alpine Geophysical Company called the "Vibra Core". In this method a steel tube containing a plastic liner is mounted in an aluminum frame. An air hammer device is mounted on the steel tube in such a way as to allow the tube to be driven into the bottom. The tremendous advantage of this device is that the unit can be operated over the side of a barge without anchoring the barge. The unit is picked up by a crane and set over the side on the bottom. Air lines connected between the barge and the air hammer and a cable attached between the barge and the coring device are the only connectors between the two. This allows as much as 100 feet of lateral movement by the barge, and common vertical movement of the barge is not disruptive. The principal limitation of the device is the length of core that can be taken. Alpine builds this unit with 20 ft., 30 ft., and 40 ft. core barrels. A second limitation is the fact that during the coring operation, the sediments can sometimes pack in such a way as to lock in the barrel. The operation will not secure a full core in this situation. Also, when a lithology is encountered that is too indurated to be penetrated, such as a limestone or a well-cemented sandstone, incomplete coring of the section results. In unconsolidated sediments of the type normally found in shallow marine environments and where the requirements are for data in the top 40 feet, this device is clearly the best answer.

During our operation, a converted ferry boat, which is used regularly by Marine Fisheries in their oyster rehabilitation program, was provided by Mr. Fentress Mundane, the Director of that program, as our working barge. A 30 B crane was loaded on the barge together with a 900 CFM compressor and 5 KW generator. A 20-foot "Vibra Core" was leased from Alpine Geophysical Company and two of their operators were provided as a part of the lease package. For navigation the Motorola Mini-Ranger was used.

As can be seen on the maps (in pocket), we attempted to locate the core sites at the tie points and on the ends of seismic lines as well as at points where shell was suspected. The mini-ranger makes precise relocation possible; however, because of high priority of time, we settled for approximate relocation in most cases rather than spend time maneuvering the barge for an exact relocation. A total of sixty cores were taken totaling approximately 1000 feet of core at a cost of approximately $20.00 per foot.

OFFICE AND LABORATORY WORK

The data acquired from the seismic survey are presented in the form of a continuous record section. The vertical scale of the section is in feet and the horizontal scale is related to feet indirectly by means of position marks which were recorded on the record sections and the navigation data. These position marks were plotted on the record sections so that all of the seismic data can be located on the ground with considerable precision (±3 feet). The appendices contain some examples of the seismic data in the vicinity of located shell deposits. All the seismic data are on permanent file in the Geology and Mineral Resources Section of the Division of Earth Resources and may be reviewed by contacting the Section.

The cores were retrieved in plastic barrels that are 20 feet long and 3.5 inches in diameter. For ease in handling, the cores were cut into 3 foot lengths. In the laboratory these 3 foot sections were split lengthwise with a diamond saw and were then photographed and described as to lithologies and shell content. Two types of photographs were taken: 4 X 5 inch color prints and 35 mm color slides. Five cuts of each core were then preserved in plastic bags for future studies of paleontology, sedimentary petrology, and whatever other geologic studies may arise for which the data would be useful. From those cores, in which oyster or clam shells were encountered, a large sample was taken for volume analysis of the components in the shell section plus chemical analysis of the shell to determine the percentage of calcium carbonate. Sample logs were hand plotted for the ten holes which indicated possible commercial shell deposits. These logs are included with this report.

Although the color prints were not reproduced for the published report, they, along with 340 color slides, are a part of the permanent file. Both the prints and the slides are available to any interested person for viewing at the laboratory of the Geology and Mineral Resources Section in Raleigh. Copies can be made of all or any part of the set of color slides at additional cost.

INTERPRETATION AND RESULTS

Two steps were necessary in the interpretation of the subbottom profiling data. Prior to the coring operation, the profiles were reviewed in some detail to determine if sedimentary structures seen on the profiles could be interpreted as shell beds. We assumed that the shell would present a very hard, seismically fast layer which would generate a reflection on the profiles. To aid this determination, we had some core data which had previously encountered shell. We picked 94 sedimentary structures in this manner and located 200 coring sites. The maps included with this report indicate the location of interesting sedimentary structures noted during this analysis which we did not core, as well as the location of 60 core holes.

Upon completion of the coring and analysis of the lithology, the core data was plotted on the seismic profiles. The intervals in which shell material was encountered were then correlated on the seismic profiles in an attempt to establish the lateral extent and thickness of the deposit. We were somewhat frustrated in this attempt by the fact that bedding of any sort has a very erratic lateral extent in the upper twenty feet of sediment in this area. We were unable to correlate any unit further than a mile without substantial changes in lithology. This suggests very rapidly shifting sedimentary environments with changing rates of depositional energy. The range of clastic sediment sizes and types testify to open bay, stream channel, back bay, beach, and deltaic regimens in areas that are now all open bay. These paleoenvironments are all represented in the top 15 feet of sediment.

Because it is impossible to contract for this type of coring on other than some sort of cost plus basis and because the budget was very limited, we designed the coring program so that we could suspend operations when the money ran out. That situation occurred after ten days of operation, during which we secured 60 cores.

Ten of the cores that were taken encountered 1 foot or more of shell material. Each of these sites, after review of the seismic data, were mapped for bathymetry, overburden thickness, and shell thickness. Since the oyster shell unit exhibited more continuity across the study area, it was the unit which was mapped and from which reserves were calculated. The scattered clam shells and shell hash were not mapped. The shell isopach maps included with this report show the oyster shell thickness at each of these core sites. As the maps indicate, there are three broad areas of interest designated A, B, and C. Within these areas there are nine shell prospects. One through five are in Area A, six is in Area B and seven, eight and nine are in Area C. Core logs included with this report as Appendix I contain a description of the lithology, a sieve analysis of the shell sections, and an acid test of the shell to give an approximation of the $CaCO_3$ content where the shell was thick enough to be commercial.

Prospect 1 - Haulover Point

In this area 3 cores were taken that encountered 1 foot or less of clay with scattered oyster shells. The volume encountered was not commercial; however, the area warrants more coring. Three core logs, numbers 42, 43, and 44, in Appendix 4 describe the sedimentary section. No screening or other laboratory tests were carried out on samples from this site.

Prospect 2 - Peter Mashoes Creek

Substantial shell was encountered in this area in five cores, numbers 38, 39, 40, 55, and 57. There are actually two shell banks in this area; one consists of oyster shells in a clay matrix, and the other contains clam shells in a sand matrix. As stated previously, the oyster shell unit was more contiguous and was the unit mapped. In a 2 mile long by 3000 foot wide area, there is a potential for 8,960,000 cubic yards of oyster shells which averages 99.5% $CaCO_3$. The site needs additional coring to determine the precise shell reserves. The shell occurs in the top 10 feet of sediment and dredging would require some sediment control since the shell occurs in a plastic clay matrix which would present some settling problems. Using a fairly coarse screen, perhaps 1/4" mesh, would minimize the problem since the clay would not be completely disintegrated in this process (see discussion on dredging and the environment).

Prospect 3 - Collington Shoals

Shell was encountered in three cores, numbers 58, 59, and 60, which indicate an area of about 3 square miles containing an average of one foot or less of shell in a clay section 4.5 feet thick. The section is in the top 6 feet of sediment. The matrix is the same as in prospect 2, and the comments regarding dredging also apply here. The reader should also understand that since everything but the shell is returned to the sound bottom, no substantial change in water depth is likely to result from dredging this shell body. We can estimate a potential of 15,000,000 cubic yards of shell in this area.

Prospect 4 - Mashoes Light

Core number 35 had about 1.1 feet of oyster shell, all within the clay section. This by itself is not commercial. However, shell occurs in a plastic clay unit throughout this area, and the clay unit is 5.4 feet thick in this core. Additional coring in the vicinity of this core should reveal a thicker shell

section. The seismic profile, line 4W, indicates that there is clay with possible shell 1,430 feet along the profile. No laboratory testing was done on this core.

Prospect 5

Three cores encountered oyster shell in this area, 28, 30, and 52. Seismic profile 2W indicates the possibility that the oyster shell unit may be continuous from core hole 58 in prospect 3 to core hole 28 in this prospect. That is, the clay bed that the shell occurs in could be continuous. The amount of shell present must be determined by additional coring. We can say that everywhere along the line that a core was taken at least 1 foot of oyster shell was encountered, and those shells overlay a coarse sand unit that contains shell hash and clam shells. The southern portion of the area covered by this prospect has an oyster shell potential of 3,000,000 cubic yards, not counting the clam shells. There is also sand and gravel in this prospect which was not evaluated.

As elsewhere, the oyster shells occur in a clay matrix which in this case is 4 to 9 feet thick. Shells are generally scattered throughout this unit but may be locally concentrated. It should be noted that while shell nearly always occurs in relationship with the shoal areas in the sound, the deposits are by no means restricted to these areas. The $CaCO_3$ solubility test reveals the oyster shells to be 94% to 96% $CaCO_3$, and the clam shell material to be about 80% $CaCO_3$.

Area B

Prospect 6 - Croatan Channel

This prospect lies between channel marker "13" and "11" about 70 yards west of the channel marked on USC and GS chart 1229. One core, number 14, located at the intersection of seismic profiles S and V encountered the clay unit at 1.7 feet and cut 7.3 feet of clay with 3.0 feet of oyster shells. Approximately 19.6% (or 0.6 feet) of the interval is shell. The $CaCO_3$ solubility test indicates the shell to be 98.6% $CaCO_3$. Review of lines S and V indicates the deposit is approximately 500 feet wide in the east-west direction and 2000 feet long along line V. The potential is about 160,000 cubic yards. The seismic profiles show indications east and west of profile V where additional coring could prove productive.

Area C

Prospect 7 - Croatan Sound Marker "21"

This prospect lies on the east side on the Croatan Channel between marker "19" and "21" on the USC and GS chart 1229. The shell unit is encountered in core hole number 12 at 1.7 feet and extends to 2.2 feet. Seismic profile V indicates the unit may extend approximately 2000 feet north-south. Previous coring done in the vicinity by Langenfelder Associates indicates the unit is widely present in the area, particularly south to prospect 9. Additional coring will be necessary in order to estimate the full shell potential (see discussion on prospect 9).

Prospect 8 - Position Mark "23"

This site must be located with the navigation data. Position mark "23" can be found on seismic profile U and core hole number 8 is just south of the position mark on line U. This core hole penetrated 20 feet of clay and very fine sand typical of the oyster shell unit. Oyster shells were encountered in the core from 17.2 feet to the bottom of the hole, and we had not penetrated below the oyster shell bearing unit at that point. About 13% of the section is oyster shell containing 94.9% $CaCO_3$. The seismic profile indicates that the unit is continuous southward for another 2000 feet. There are also indications of areas worthy of additional coring northward along line V. We can estimate a minimum potential in the vicinity of core hole number 8 of 230,000 cubic yards of oyster shells.

Prospect 9 - Cedar Bush Bay

Core hole number 11 in this study and five core holes drilled by Langenfelder Associates encountered an average of 2 feet of shell in a clay section approximately 6 feet thick. In core hole number 11 the shell unit starts at 0.9 feet and extends to 3.3 feet. The section is approximately 23.6% shell which contains 97.5% $CaCO_3$. Additional coring needs to be done to outline all of the reserves in this area. We estimate the shell potential at 1,200,000 cubic yards.

DREDGING AND THE ENVIRONMENT

There is a fundamental law in geology called the doctrine of uniformitarianism. This doctrine says that the key to the study of past physical processes is the observation of present physical processes. If this dictum is reversed in the present study, a very important conclusion can be reached. That is, any attempt at preservation in the marine areas under study is doomed to certain failure with time. This statement applies to attempts to preserve one area as fresh water or another as saltwater. It applies to attempts to preserve bathymetry. It applies to attempts to preserve marsh in one area and open water in another. The certain lesson to be learned from a review of the top 20 feet of sediments in the bottom of

the sound is that rapid change is the rule here, most certainly not the exception. What we may consider of economic or aesthetic importance today is not to be handed down to future generations in the present form. The natural processes that rule this area are marshalled in opposition to the status quo. A mere 6 foot rise in sea level would virtually rewrite the face of the entire area. Such movements have occurred continuously over the past few thousand years as is indicated by the sediments recovered in this study. Much more recently, Currituck and Albemarle Sounds were saltwater bodies year around fed not only by Oregon Inlet but also by an inlet in the vicinity of Corolla. It was during this period that the shell deposits currently under investigation were formed.

The present water depth throughout the area averages less than 10 feet. With the very large open expanses available to the wind, such a shallow water environment will stir and constantly move bottom sediments. The water will be very turbid during bad weather. Salinities will and do vary widely with wind and with seasonal runoff brought into the sounds by the rivers. Seasonal water temperature changes are also the norm. All of these factors suggest that the marine biota that subsist here are very flexible and that man's activities can, at most, temporarily influence only a minor portion of the system detrimentally.

Generally speaking, the following catagories of subjects bear on a marine ecosystem: physical aspects - salinity, bathymetry, currents, turbidity, and temperature; biology - varieties of fish, benthic and foraminiferal invertebrate biota, water fowl, and the food chain (plant and animal); chemistry - chlorinated hydrocarbons in organisms and sediment column, pesticides, PCB and trace metals in sediment column, and contained water; geology - type and distribution of sediments and sedimentary structures; and economics - the economics of shell dredging versus the economic hazards to fish and marine biota nurseries, to sports and commercial fishing, to water recreation, or other economic or aesthetic use of the water environment.

To keep the discussion from evolving into a discourse on marine biology and physical oceanography, the subjects will be dealt with in terms of dredging. This is an alternative to the baseline approach which is recommended when an entire area is subject to environmental change and there is to be an attempt to monitor the direction and rates at which change is occurring.

The process of dredging for shell involves cutting into the bottom of the sound to some predetermined depth, sucking the sediments up by use of large pumps, discharging the gross pumpage across screens, and returning to the sound bottom all but the shell of predetermined size. The discharge back to the sound is by gravity settling.

Physical Effects

Dredging could affect salinity in three ways. The material being cut into could contain large percentages of $NaCl$. If the bathymetry is substantially changed, currents of saline water could encroach into areas where they would not normally go. Finally, the dredge could encounter a fresh or salt water acquifer under a clay seal with positive pressure. We can say with certainty that none of these conditions will be met in the areas so far studied.

Water depth can be substantially changed as a result of dredging. However, in the area under study the concentration of shells suggests that the normal total change will be no more than 2 feet.

Dredging has only a nominal effect on current as in the case of transgressing salt water. However, it is important to know the current patterns in an area for different cases of wind, tide, and river discharge in order to predict any adverse siltation effects brought about by dredge discharge.

Turbidity looms as a problem in the study area primarily because the oyster shell deposits were all associated with a matrix of plastic clay and very fine-grained quartz sand. Considering the relatively small area a dredge can cover as opposed to the turbidity caused in this area by a high wind and the obvious additional fact that the biologic environment has adapted to considerable turbidity because of the natural processes at work in the area, the logical conclusion is that any damage done by dredging will be local and temporary for most of the study area. Marsh area would have to be given very special attention, however, since both marine biota and water fowl depend on the marsh environment, and even temporary destruction would have some disastrous short term economic impacts.

Biological Effects

Fin fish can be affected in two ways by dredging: first by an increase in turbidity and second by a possible disruption of their normal food supply. The local nature of dredging normally causes only a change in fish habitat during the dredging operation. These statements are also true for benthic biota which can move to avoid the dredge and return when favorable conditions are re-established. Bottom dwelling organisms which are an important element in the food chain are destroyed by dredging and normally require two or three years to re-establish themselves provided bottom conditions have not been so altered as to make that impossible. Great care needs to be exercised in determining areas to be dredged so as to minimize this hazard. Areas with substantial plant food for water fowl also need to be avoided or the plant regimen needs to be re-established after dredging.

A lot of rhetoric has been offered regarding the potential danger of resuspending sediments that may contain chemicals adverse to the biota. A number of cores, particularly clays, contained connate water with hydrogen sulfide gas. If released in sufficient amounts, this gas could be chemically adverse to the biota, but this would require a rather massive resuspension not contemplated by shell dredging.

As was mentioned in the section dealing with interpretation of data, the oyster shell material is contained in a matrix of plastic clay and very fine-grained quartz sand. This is typical of a depositional environment with a very low energy level. The shell units frequently overlay a coarse sand and shell hash unit which is typical of a forebeach environment. The overburden, if any occurs, is usually clay or fine sand. Typically, the clay material is a stiff to very plastic material which does not easily disintegrate in water. It is our opinion that screen sizes will be important in reducing turbidity with this clay in any dredging operation.

Based on data obtained by the Army Corps of Engineers in environmental impact statements on San Antonio Bay in 1971, one dredge can produce approximately 1,500,000 cubic yards of shell per year with a value of approximately $3,000,000.00. The operation would employ the services of about 90 people, 32 barges, and 8 tug boats. The average annual payroll would amount to $710,000.00. The material is valued as a source of chemical grade lime, as poultry grits, and as oyster clutch material. It also can be used to manufacture portland cement. The foregoing is offered in the environmental section of this report because it is needed to compare the value of alternative resources.

RECOMMENDATIONS

The next logical step would be a closely supervised test dredging project. We recommend the Cedar Bush Bay Area as a good place to conduct such a test. Prior to testing, base line data should be gathered at the site so that the area can then be monitored for any adverse environmental impacts. Particular attention should be given to the possible adverse effects of siltation and turbidity.

We further recommend that additional funds be sought to complete the coring program in this area. The data should be reviewed not only for shell but for a sand and gravel inventory. Substantial gravel deposits were noted during this study. Since the northeastern section of North Carolina is in very short supply of these commodities, the feasibility of extracting these materials at the same time as the shell needs to be evaluated.

APPENDICES

APPENDIX 1: BUDGET SUMMARY

CPRC Funds

Lease and rental of equipment, travel expenses, and purchase of expendable supplies through June 30, 1975		$ 8,498.00
Lease and rental of equipment, travel expenses, and purchase of expendable supplies and equipment through June 30, 1976		26,502.00
	TOTAL	$35,000.00

North Carolina Department of Natural and Economic Resources Funds

1. Through June 30, 1975		
Division of Earth Resources		$ 4,679.44
Division of Marine Fisheries		3,444.60
	TOTAL	$ 8,124.04
2. Through June 30, 1976		
Division of Earth Resources		$12,886.21
Division of Marine Fisheries		9,359.15
		$30,369.40

APPENDIX 2: EQUIPMENT AND PERSONNEL

1. Geological and geophysical field and interpretive personnel and equipment.

   a) Two geologists and one geologic technician as needed. Two technicians, part time, as needed. (Division of Earth Resources)

   b) RTT-1000 Raytheon 3.5 Khz subbottom profiler on lease from Raytheon Corporation.

   c) Alpine Geophysical Company 20 foot "Vibra Core" and two technicians on lease from Alpine Geophysical Company.

   d) Crane, 900 cfm air compressor and miscellaneous equipment on lease from Waff Brothers Heavy Equipment Company.

2. Navigation, boat location, survey personnel and equipment.

   a) A registered surveyor and one technician. (Division of Marine Fisheries)

   b) Range-range boat positioning equipment, the Motorola Mini-Ranger, on lease from Motorola Corporation.

3. Boat operators, boats and barges, as needed.

   a) One seventeen foot and one fifteen foot boat as needed with operator. (Enforcement Division of Marine Fisheries)

   b) One self-propelled barge with a 3 man crew as needed in the coring operation. (oyster rehabilitation program of Marine Fisheries)

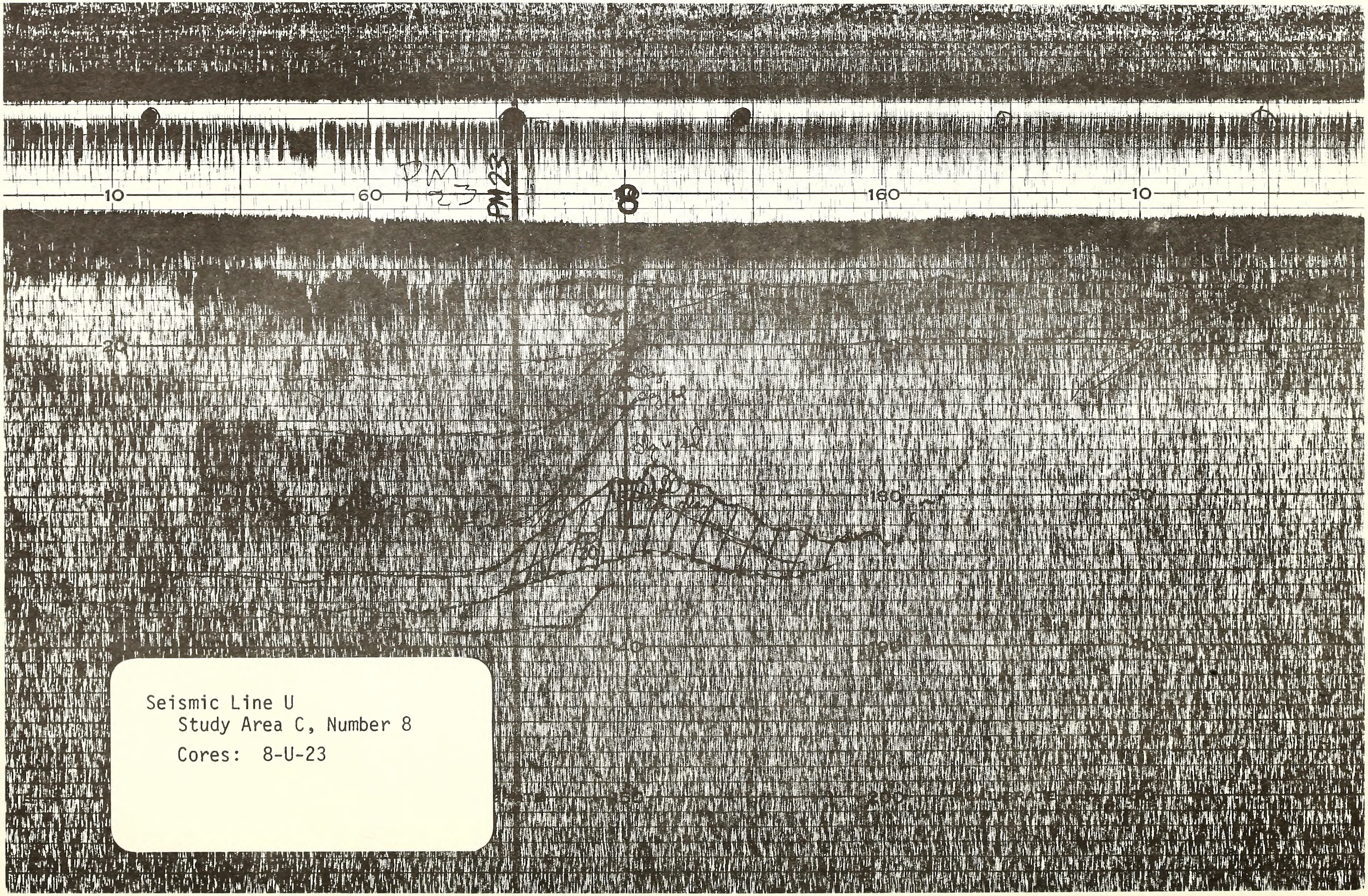
4. Computer technology and hardware to handle the navigation data.

   a) One computer specialist from Marine Fisheries and two program analysts on contract from the Computer Science Department of North Carolina State University as needed to convert range-range data to x-y coordinate data and plot the boat tracks using the "Cal Comp" plotter.

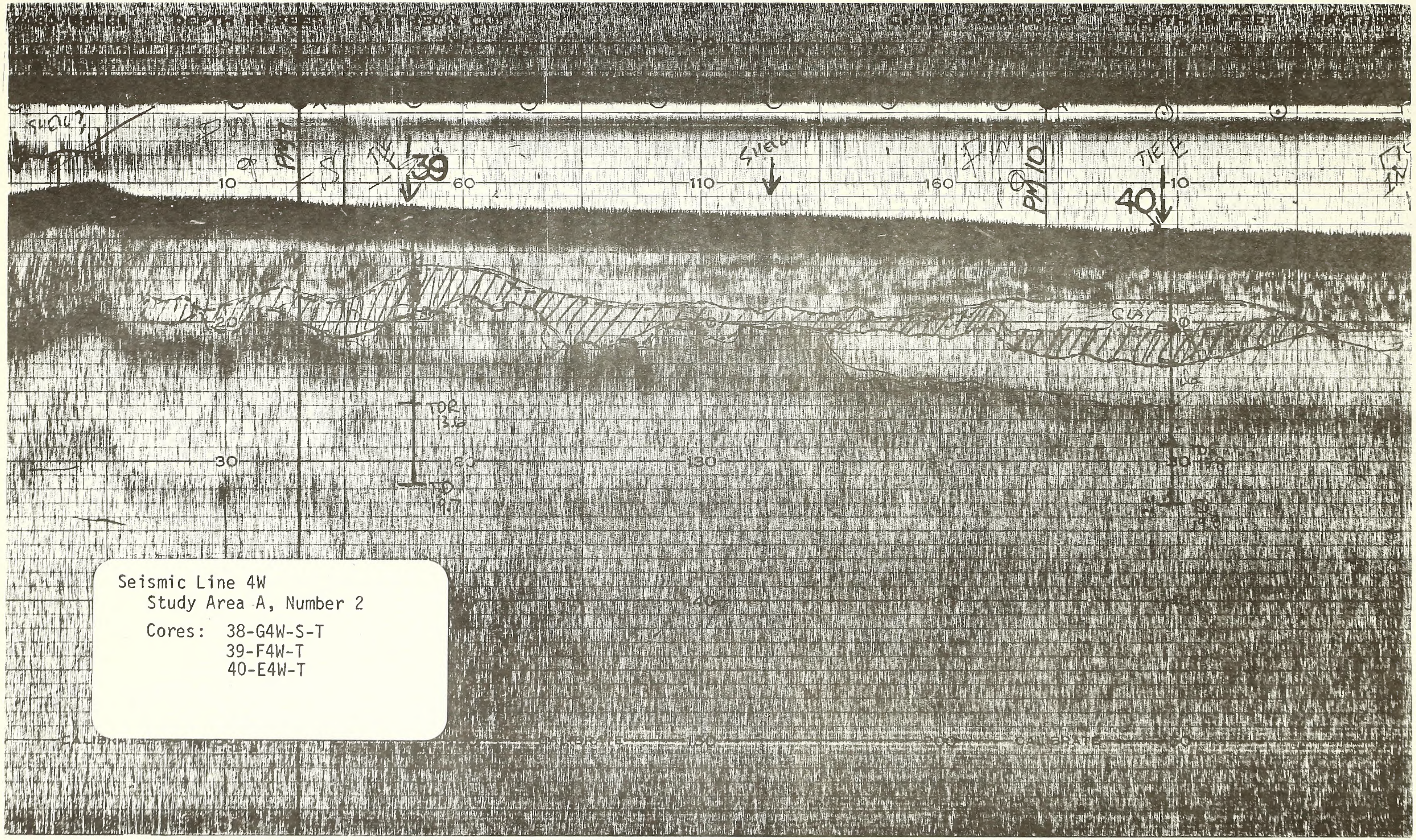
5. Marine biology and physical oceanography, as needed. (Division of Marine Fisheries)

6. Administrative support was provided by each Division handling records and invoices for personnel and equipment furnished for the project. Mrs. Myrtle Tyson handled budget management on behalf of Mr. Stephen Conrad.

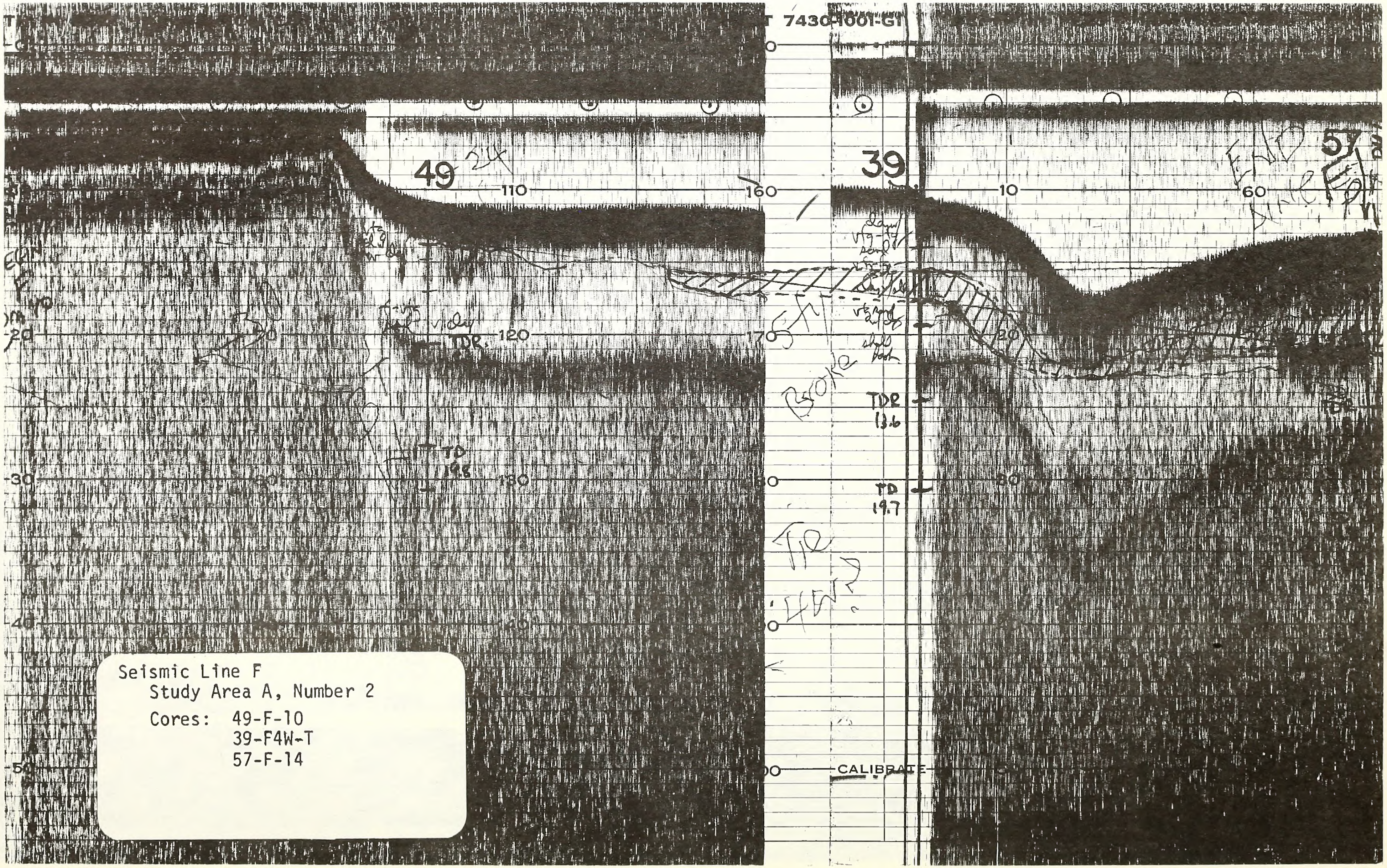
APPENDIX 3: SELECTED SEISMIC PROFILES



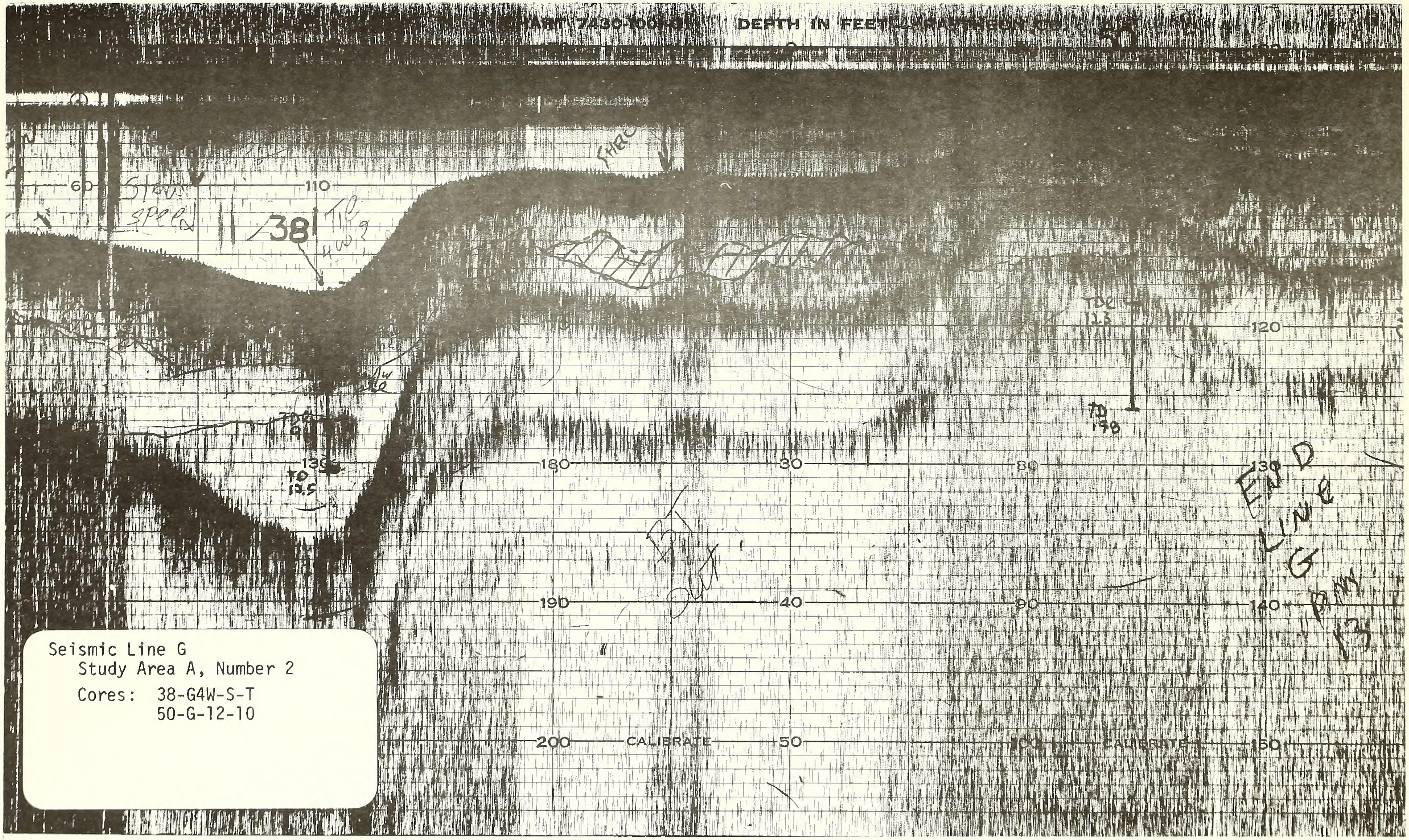
Seismic Line U
Study Area C, Number 8
Cores: 8-U-23



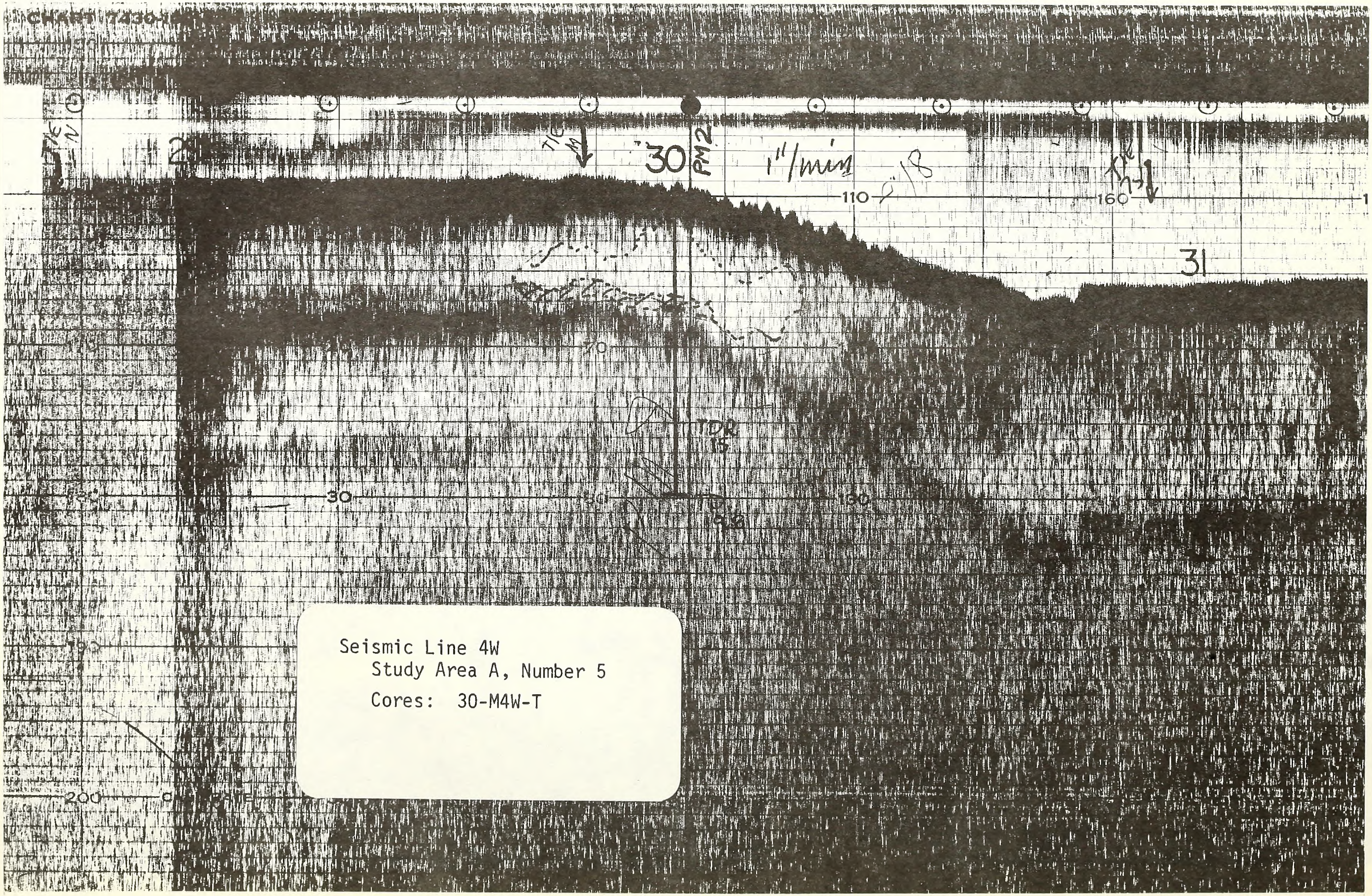
Seismic Line 4W
Study Area A, Number 2
Cores: 38-G4W-S-T
39-F4W-T
40-E4W-T

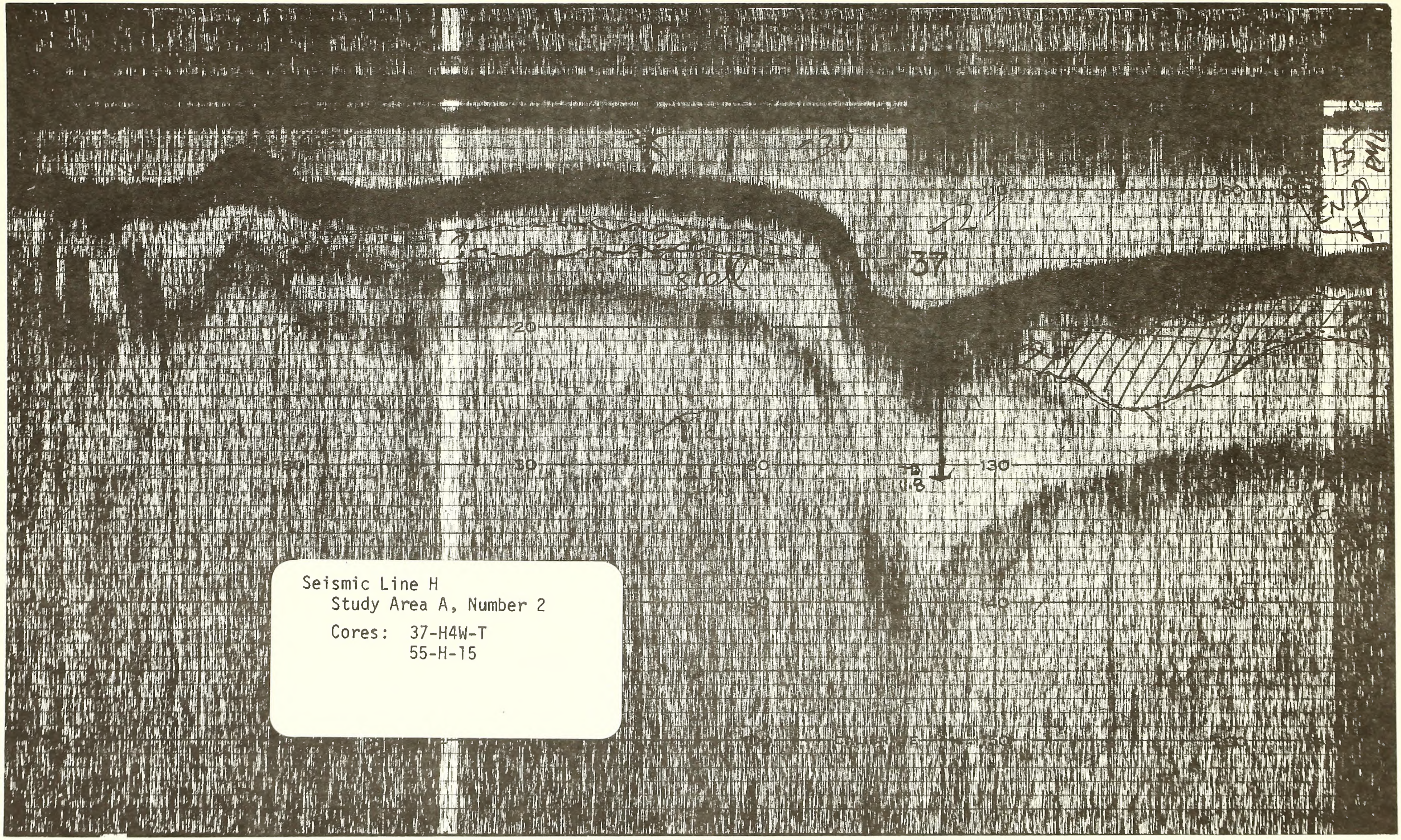


Seismic Line F
Study Area A, Number 2
Cores: 49-F-10
39-F4W-T
57-F-14



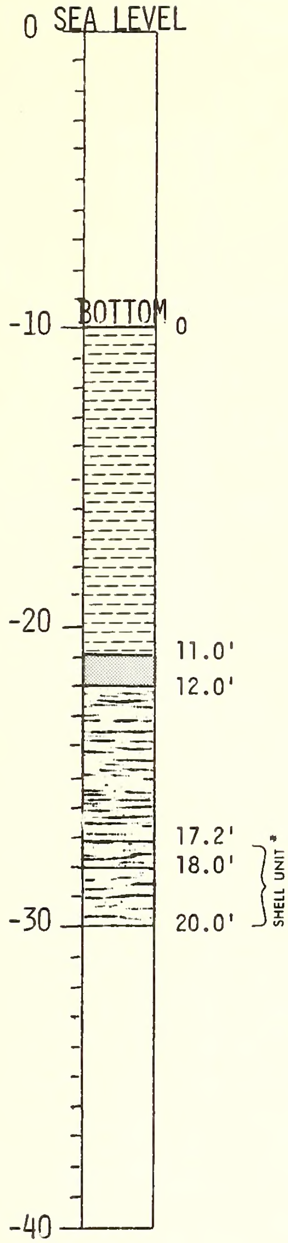
Seismic Line G
Study Area A, Number 2
Cores: 38-G4W-S-T
50-G-12-10


Seismic Line 4W
Study Area A, Number 5
Cores: 30-M4W-T



Seismic Line H
Study Area A, Number 2
Cores: 37-H4W-T
55-H-15

APPENDIX 4: CORE LOGS



dark- to light-gray, plastic clay

very fine-grained sand with some clay

plastic clay with fine-grained sand

clay with sand and oyster shell

as above

Note: The core was not deep enough to evaluate total shell thickness, so the seismic interpretation of a total of 7 feet was used.

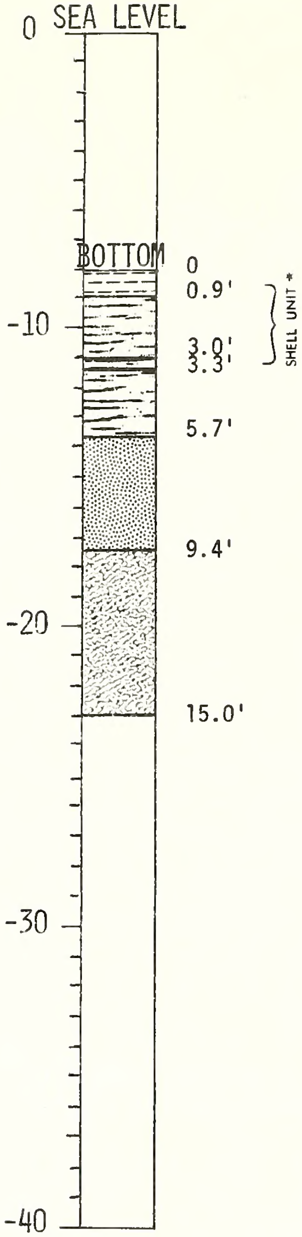
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.1574"	71.2 gms	13.1%
.0787	8.7	1.6
.0394	19.9	3.7
.0197	60.3	11.1
.0098	141.8	26.0
.0098>	243.1	44.5

The commercial shell was retained on the 0.1574" screen. These were oyster shells. A 20% HCl solution digested 67.6 gms or 94.9% and left a residue of 3.6 gms or 5.1%.

The estimated 7 foot segment analyzed contained .92 foot of shell.

CORE NUMBER 11
AREA C PROSPECT 9



dark plastic clay

very fine-grained sand with clay and oyster shells

as above

as above with clay increasing

very fine- to fine- to medium-grained sand; grading downward

coarse-grained sand-gravel

*Shell Unit Screen Analysis

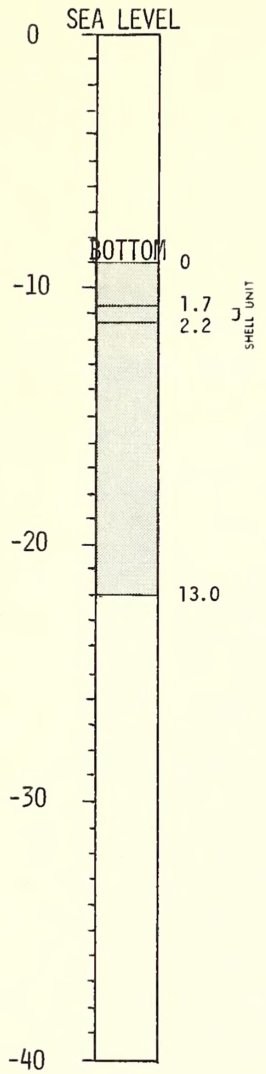
Screen Size	Sample WT.	Percent
.1574"	127.0 gms	23.6%
.0787	15.4	2.9
.0394	17.5	3.3
.0197	46.0	8.6
.0098	149.4	27.8
.0098>	182.9	33.8

The commercial shell was retained on the 0.1574" screen. These were oyster shells. A 20% HCl solution digested 123.8 gms or 97.5% and left a residue of 3.2 gms or 2.5%.

The 2.4 foot segment analyzed contained 0.57 foot of shell.

CORE NUMBER 12

AREA C PROSPECT 7

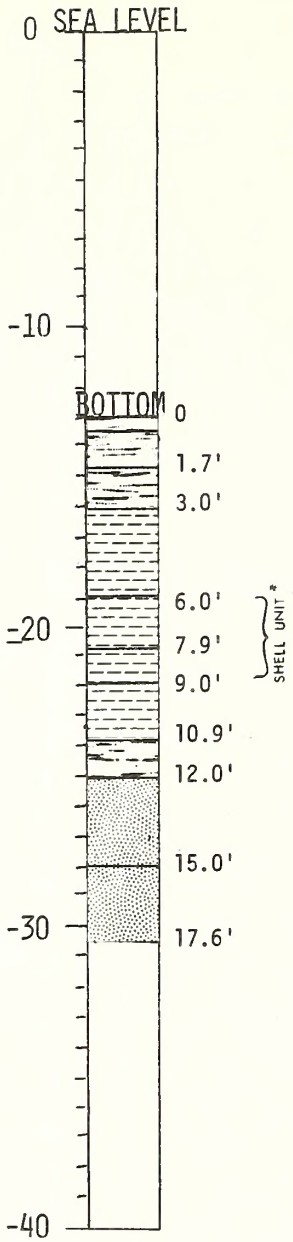


very fine- to fine-grained sand with some clay

shell unit as above with oyster shell

very fine- to fine-grained sand with some clay

CORE NUMBER 14
AREA B PROSPECT 6



fine- to medium-grained sand with some clay

very fine-grained sand with clay; minor shell

dark plastic clay; scattered shells

as above with oyster shells

as above

dark plastic clay

very fine- to fine-grained sand with clay

fine- to medium- to coarse-grained sand

as above

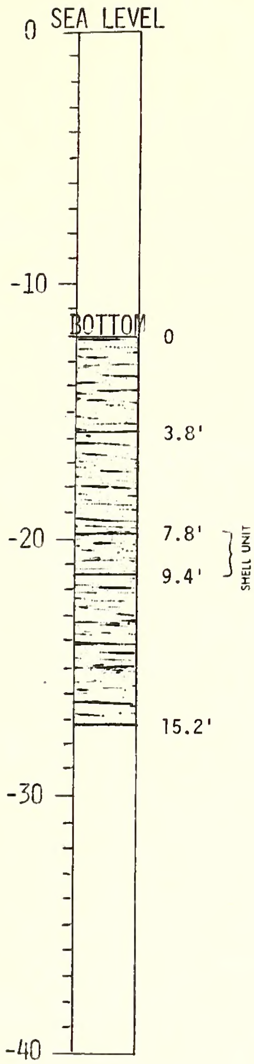
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.0787"	105.7 gms	19.6%
.0394	9.1	1.7
.0197	4.5	0.8
.0098	22.3	4.1
.0049	187.8	34.8
.0049 >	211.0	39.0

The commercial shell was retained on the 0.0787" screen. These were oyster shells. A 20% HCl solution digested 104.2 gms or 98.6% and left a residue of 1.5 gms or 1.4%.

The 3.0 foot segment analyzed contained 0.59 foot of shell.

CORE NUMBER 28
AREA A PROSPECT 5



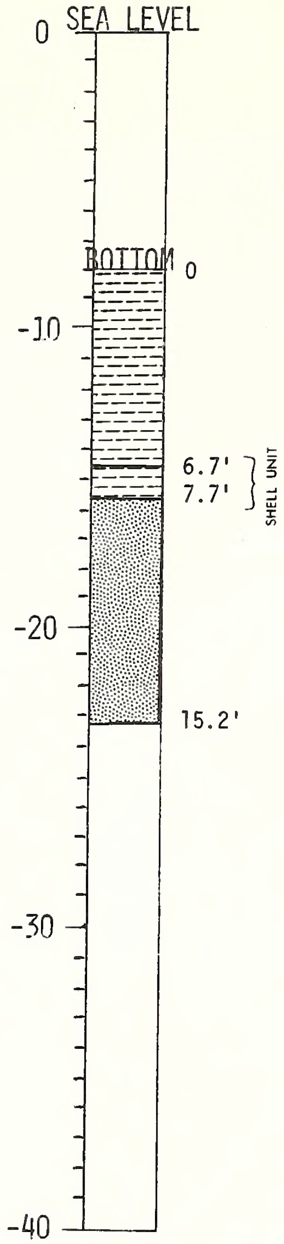
very fine-grained sand with clay and few shells

as above with scattered oyster shells

as above with oyster shells

very fine-grained sand with clay

CORE NUMBER 30
AREA A PROSPECT 5

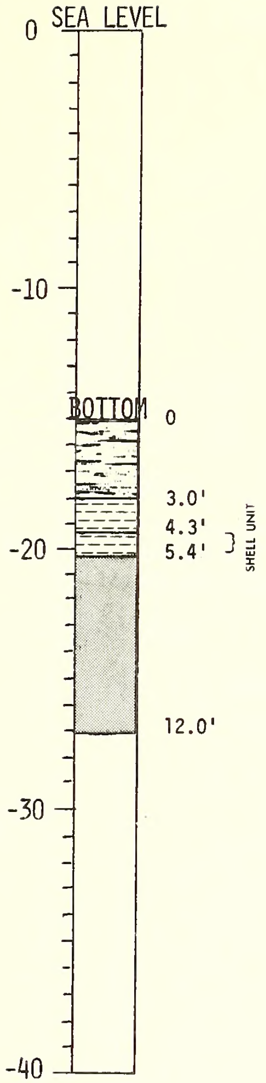


plastic clay

plastic clay with oyster shell

fine- to medium-grained, gray to yellow, quartz sand

CORE NUMBER 35
AREA A PROSPECT 4



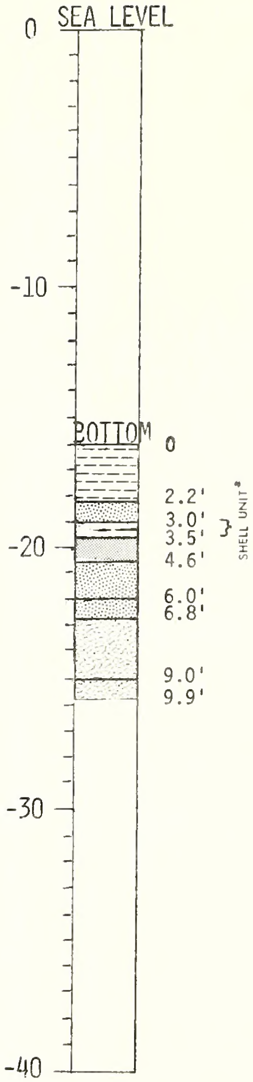
very fine-grained sand with some clay

dark plastic clay

dark plastic clay with some oyster shell

very fine- to medium-grained, light-gray sand; some coarse-grained layers

CORE NUMBER 38
AREA A PROSPECT 2



dark plastic clay

fine- to medium-grained sand; minor shell
clay with fine-grained sand; some oyster shells
very fine- to medium-grained sand with clam shells

fine- to medium-grained sand with abundant clam shells
as above

medium- to coarse-grained, gray sand

medium- to coarse-grained, yellow-tan sand

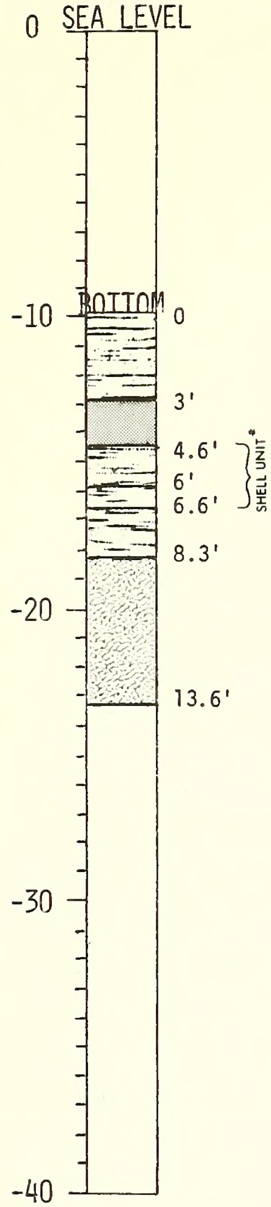
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.1574"	263.6 gms	48.6%
.0787	27.7	5.1
.0394	26.4	4.9
.0197	65.1	12.0
.0098	119.7	22.1
.0098 >	39.9	7.3

The commercial shell was retained on the 0.1574" screen. These were clam shells. A 20% HCl solution digested 255.8 gms or 97.1% and left a residue of 7.8 gms or 2.9%.

The 0.5 foot segment analyzed contained .24 foot of clam shells. The analyzed section was not the oyster shell unit and therefore was not mapped as reserves.

CORE NUMBER 39
AREA A PROSPECT 2



very fine- to fine-grained sand with clay

very fine- to fine-grained sand

dark plastic clay with some sand and oyster shells
as above

very fine-grained sand with some clay

medium- to coarse-grained sand with shell hash

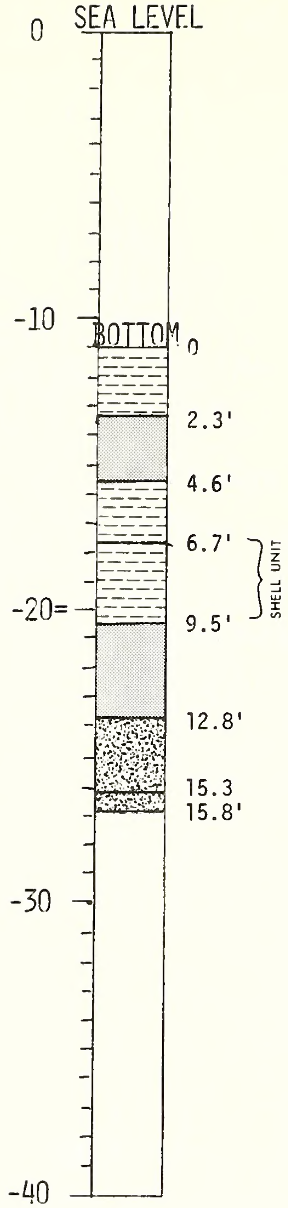
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.1574"	98.8 gms	18.3%
.0787	15.8	2.9
.0394	13.7	2.5
.0197	8.2	1.5
.0098	112.2	28.8
.0098>	290.0	46.0

The commercial shell was retained on the 0.1574" screen. These were oyster shells. A 20% HCl solution digested 96.6 gms or 97.8% and left a residue of 2.2 gms or 2.2%.

The 2.0 foot segment analyzed contained 0.37 foot of shell.

CORE NUMBER 40
AREA A PROSPECT 2



dark plastic clay

very fine- to fine-grained sand

dark plastic clay

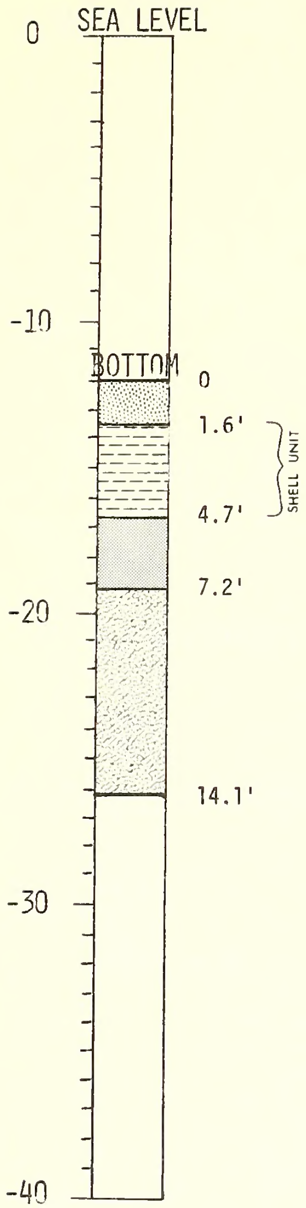
dark plastic clay with oyster shells

very fine- to fine-grained sand with clay

coarse-grained, yellow-brown gravel

coarse-grained, dark-brown gravel with shell hash

CORE NUMBER 41
AREA A PROSPECT 1

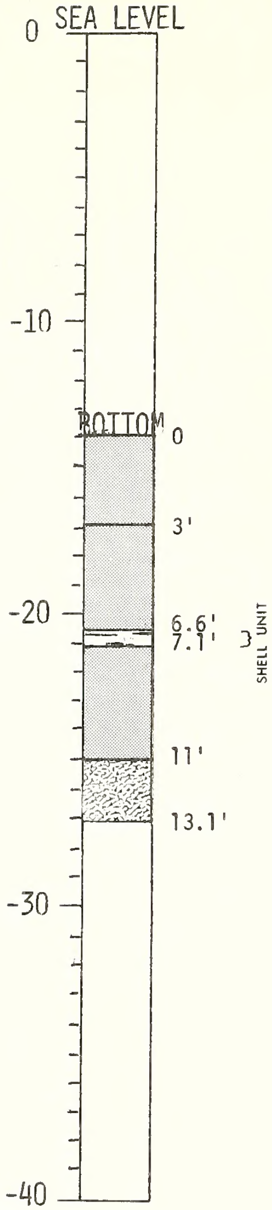


fine- to medium-grained sand
dark plastic clay

very fine- to fine-grained sand

coarse shell hash with coarse-grained sand

CORE NUMBER 42
AREA A PROSPECT 1



very fine-grained sand

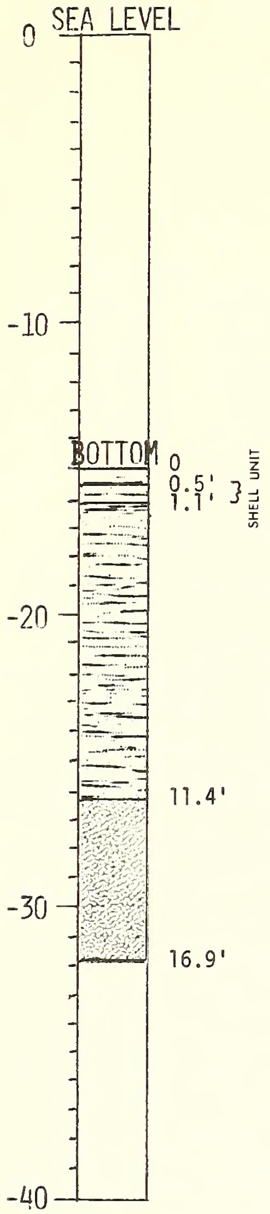
as above with shell fragments

very fine-grained sand with clay and oyster shells

fine-grained, light-gray sand

coarse-grained sand with wood fragments

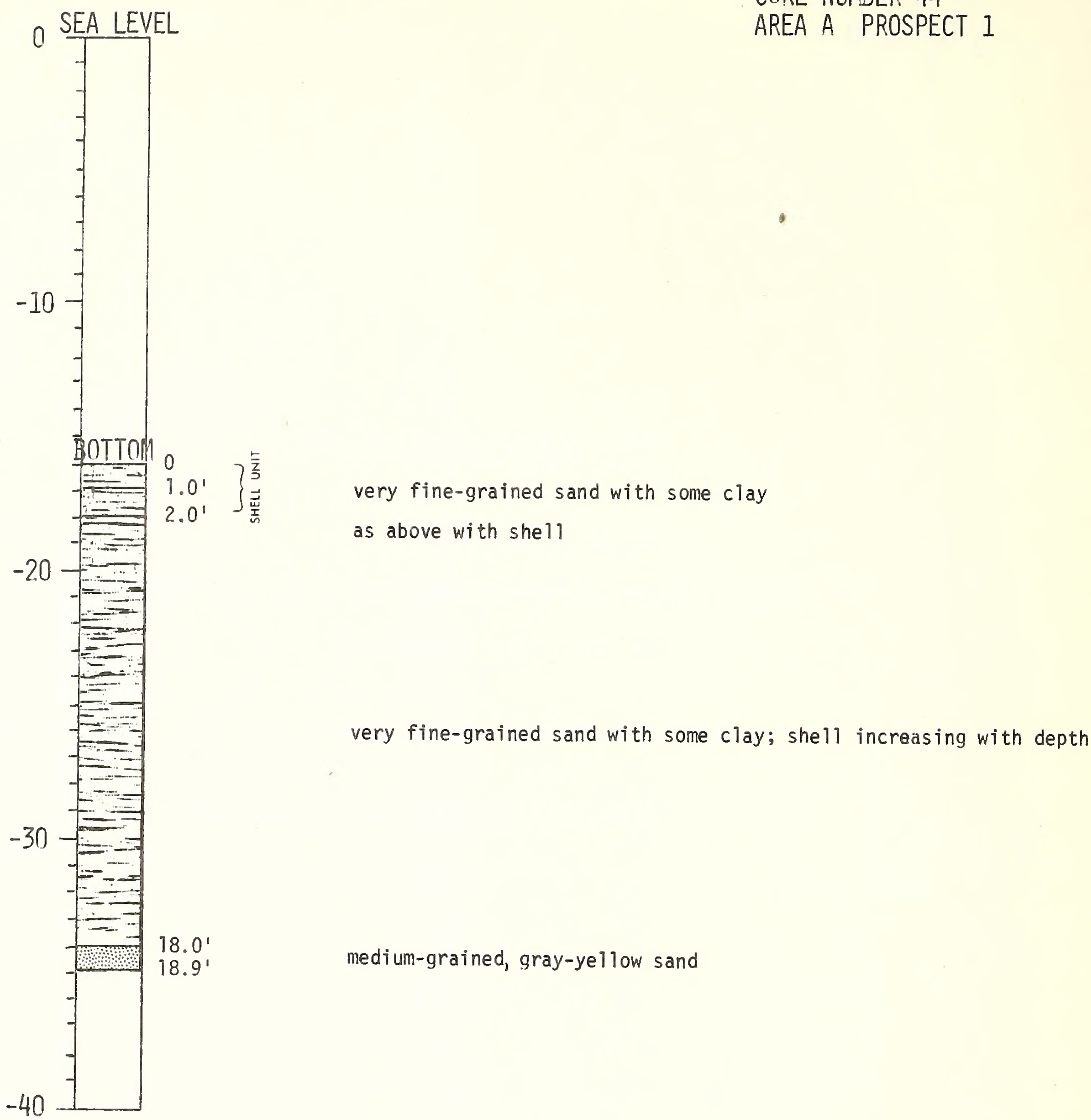
CORE NUMBER 43
AREA A PROSPECT 1



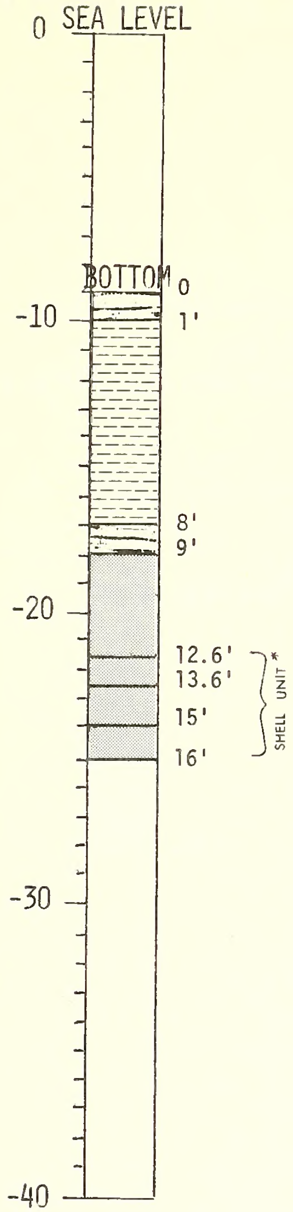
very fine-grained sand with clay
as above with shell

very fine-grained sand with few shells and some clay

coarse shell hash with coarse-grained sand


0 SEA LEVEL
-10
-20
-30
-40
BOTTOM
0
1.0'
2.0'
SHELL UNIT
18.0'
18.9'
very fine-grained sand with some clay
as above with shell
very fine-grained sand with some clay; shell increasing with depth
medium-grained, gray-yellow sand

CORE NUMBER 51
AREA A PROSPECT 5



very fine-grained sand with clay

dark plastic clay

very fine-grained sand with clay

very fine- to fine-grained sand

very fine- to fine-grained sand with shell hash

as above

as above

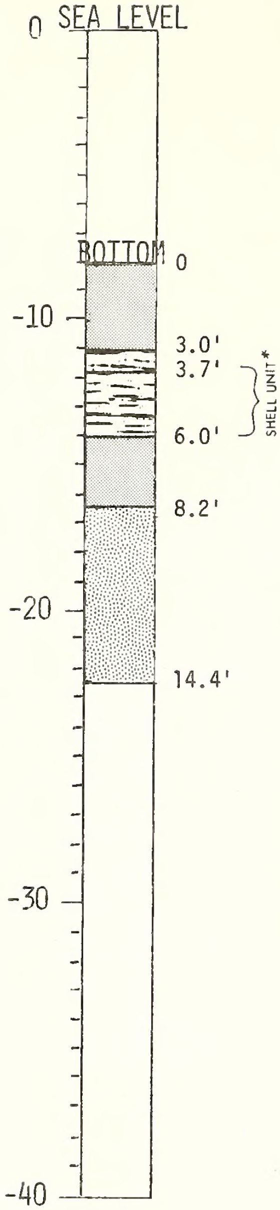
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.0787"	102.9 gm	19.5%
.0394	72.4	13.7
.0197	216.7	41.1
.0098	107.4	20.4
.0049	21.3	4.0
.0049 >	6.8	1.3

The commercial shell was retained on the 0.0787" screen. These were clam shells. A 20% HCl solution digested 60.1 gms or 79.1% and left a residue of 42.8 gms or 21%.

The 3.4 foot segment analyzed contained .66 foot of shell. The analyzed section was not the oyster shell unit and therefore was not mapped as reserves.

CORE NUMBER 52
AREA A PROSPECT 5



very fine- to fine-grained, tan-gray sand with some shell

very fine- to fine-grained sand with clay

very fine- to coarse-grained sand with dark plastic clay and oyster shells

fine-grained sand

fine- to medium- to coarse-grained sand with gravel

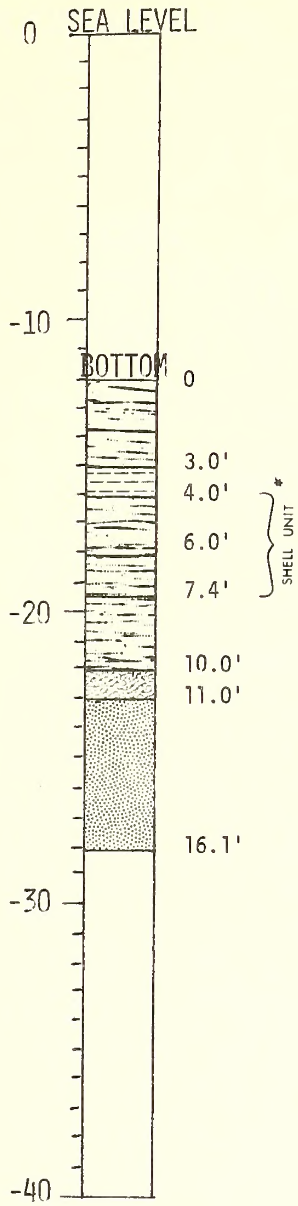
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.1574"	160.7 gms	29.8%
.0787	24.2	4.5
.0394	32.5	6.0
.0197	57.4	10.6
.0098	87.4	16.2
.0098 >	177.4	32.9

The commercial shell was retained on the 0.1574" screen. These were oyster shells. A 20% HCl solution digested 151.1 gms or 94% and left a residue of 9.6 gms or 6%.

The 2.3 foot segment analyzed contained 0.68 foot of shell.

CORE NUMBER 55
AREA A PROSPECT 2



very fine-grained sand and plastic clay with minor clam shells

dark plastic clay

dark plastic clay, fine-grained sand with oyster shells

as above

dark plastic clay, fine-grained sand

medium- to coarse-grained sand with gravel

fine- to medium-grained sand, interbedded yellow-tan-gray-black layers

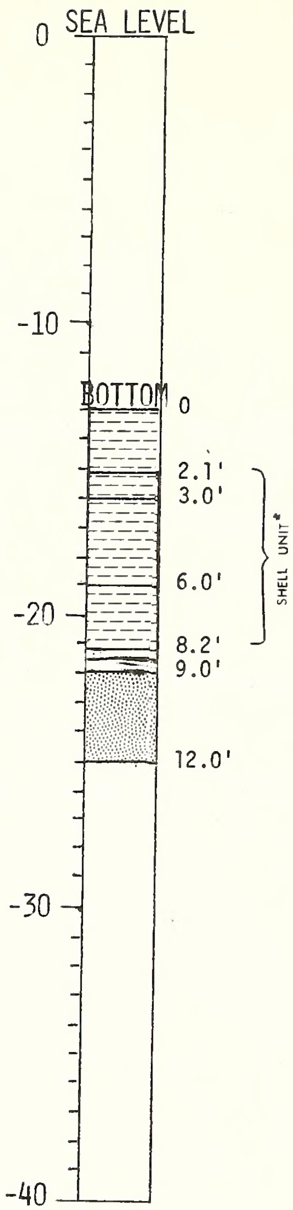
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.1574"	154.7 gms	37.0%
.0787	13.8	3.3
.0394	13.8	3.3
.0197	15.2	3.6
.0098	22.2	5.3
.0098 >	199.0	47.5

The commercial shell was retained on the 0.1574" screen. These were oyster shells. A 20% HCl solution digested 153.2 gms or 99% and left a residue of 1.5 gms or 1%.

The 3.4 foot segment analyzed contained 1.26 feet of shell.

CORE NUMBER 57
AREA A PROSPECT 2



dark plastic clay

as above with some sand and oyster shells

as above

as above

fine- to medium-grained sand with clay; some shells

fine- to medium-grained sand

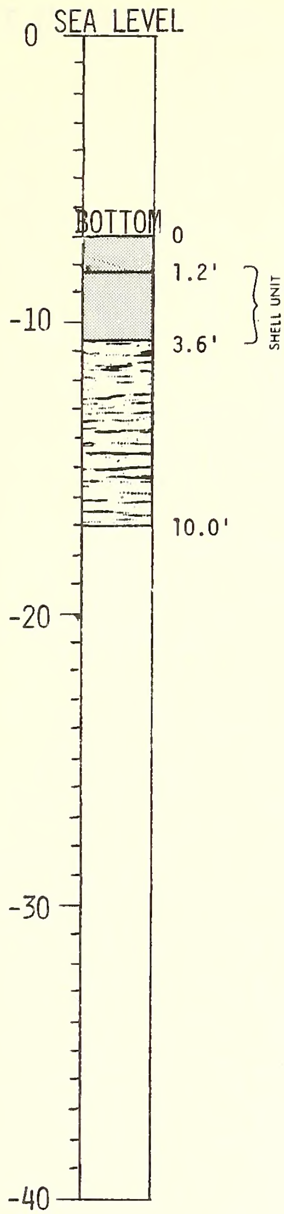
*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.1574"	187.8 gm	36.7%
.0787	14.2	2.8
.0394	12.1	2.4
.0197	20.5	3.9
.0098	2.6	0.5
.0098 >	275.0	53.7

The commercial shell was retained on the 0.1574" screen. These were oyster shells. A 20% HCl solution digested 186.8 gms or 99.5% and left a residue of 1.0 gms or 0.5%.

The 6.1 foot segment analyzed contained 2.24 feet of shell.

CORE NUMBER 58
AREA A PROSPECT 3

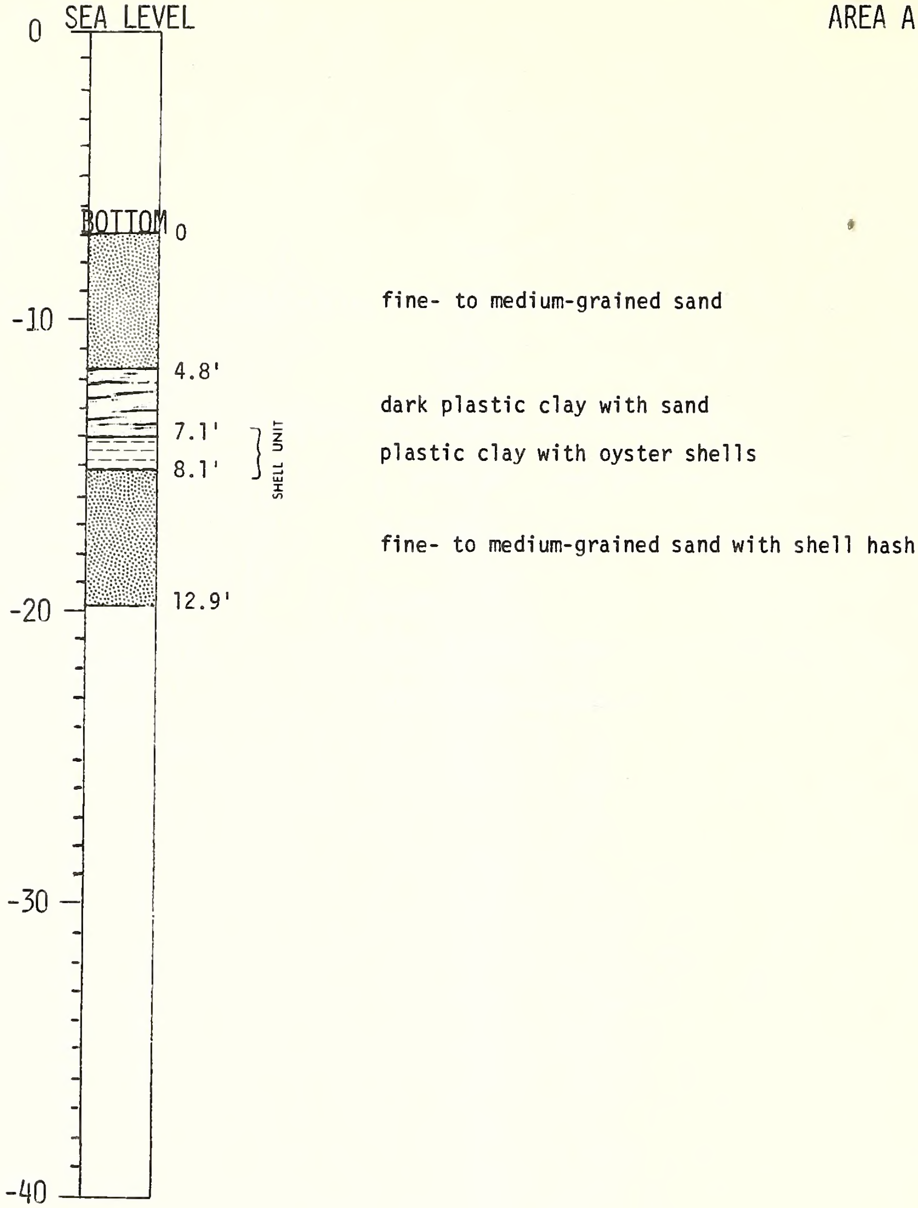


very fine-grained sand

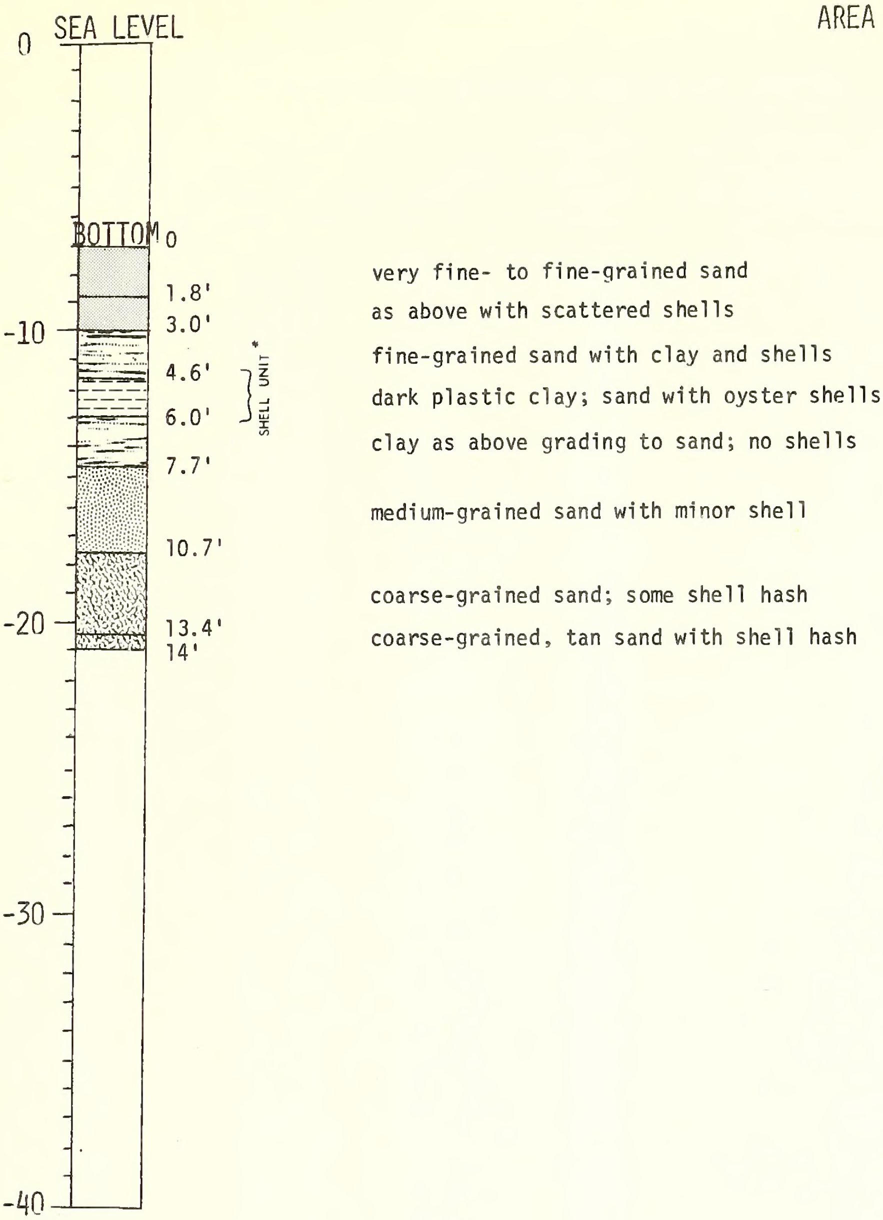
very fine-grained sand with oyster shells

fine-grained sand with clay; some shell

CORE NUMBER 59
AREA A PROSPECT 3



CORE NUMBER 60
AREA A PROSPECT 3



*Shell Unit Screen Analysis

Screen Size	Sample WT.	Percent
.0787"	76.6 gms	15.6%
.0394	6.20	1.3
.0197	11.80	7.4
.0098	98.28	20.0
.0049	140.00	28.4
.0049 >	149.42	32.3

The commercial shell was retained on the 0.0787" screen. These were oyster shells. A 20% HCl solution digested 73.3 gms or 96.1% and left a residue of 3.0 gms or 3.9%.

The 1.4 foot segment analyzed contained 0.22 foot of shell.

APPENDIX 5: CORE HOLE LOCATIONS: RANGE-RANGE DATA

Core No.	Line Designation	West Bridge Meters	West Bridge Feet	East Bridge Meters	East Bridge Feet
1	Shipyard Channel	----------------	± Bridge	----------------	
2	S-14-10	4482	14705	5746	18853
3	S-14-5	4617	15148	5260	17258
4	TV-A	6253	20516	7065	23180
5	TV-30	6394	20979	6062	19889
6	T-19	7844	25736	5875	19276
7	U-21-6	9659	31691	8130	26675
8	U-23-1	10776	35356	9581	31435
9	U-24	12010	39405	11010	36124
10	V-25-4	12535	41127	12037	39493
11	V-26	13228	43401	12909	42354
12	V-27-12	9907	32505	9907	32505
13	V-28-7	8477	27813	8430	27659
14	VS-T-31	4897	16067	4680	15355
15	VR-T-32	3885	12747	3672	12048
16	VQ-T-33	3132	10276	2710	8892
17	VP-T-34	2610	8563	2546	8353
18	V-35	2196	7205	2311	7582
19	P-5	4450	14600	1096	3596
20	Q-6	5180	16996	1956	6418
21	R-11	5701	18705	3100	10171
22	S-13	6655	21835	4210	13813
23	P-2	1183	3881	4605	15109
24	Q-8	2220	7284	4647	15247
25	R-9	3400	11155	5106	16753
26	S-15	4572	15001	6086	19968
27	T-16	5893	19335	7223	23699
28	N-28-11	12701	41672	215	705
29	4WN-T	13338	43762	847	2779
30	4WM-T	13091	42952	1157	3796
31	4W-2-4	12857	42184	1800	5906
32	4WL-T-3	12857	42184	2585	8481
33	4WK-T-22	12729	41764	3148	10329
34	4WJ-T-19	12552	41183	4424	14515
35	4W-5	12580	41275	5225	17143
36	4WI-T	12655	41521	6100	20014
37	4WH-T	12884	42272	6917	22695
38	4WG-T	13316	43690	7905	25936
39	4WF-T	14030	46032	8662	28420
40	4WE-T	14837	48680	9661	31698
41	4WD-T	15466	50744	10659	34972
42	4WC-T	16221	53221	11725	38470
43	4WB-T	16920	55515	12632	41446
44	4WA-T	17285	56712	13108	43007
45	AB-T-(B-2)	17397	57080	12599	41337
46	C-5±	16312	53520	11352	37246
47	D-6±	15647	51338	10437	34244
48	E-9±	15142	49681	9353	30687
49	F-10±	14501	47578	8682	28486
50	G-12-10±	14065	46147	7762	25467
51	M-26	11204	36760	1725	5660
52	L-25	11397	37394	2315	7596
53	K-21	11202	37654	3636	11930
54	J-20	11661	38260	4378	14364
55	H-15	12465	40898	7083	23239
56	G-12	12950	42489	8163	26783
57	F-11	13508	44320	8863	29080
58	2W/1S-12±	9607	31521	6230	20441
59	2W/2S-T-12-6	9875	32400	5002	16412
60	4S ext.	9580	31432	3510	11516

APPENDIX 6: FUTURE CORE POINTS

Line Designation	Location*	
16N	PM3	MM7
15N	PM1	MM7
14N	PM2	
	PM3	MM5
		MM9
	PM4	MM3
13N	PM1	MM2
13	PM3	MM8
	PM4	MM4
	PM5	MM4
	PM6	MM3
12N	PM5	MM4
	PM3	MM1
10N	PM1	MM2
	PM2	MM7
	PM12	
9N	PM8	MM2
	PM6	MM5
	PM6	MM1
8N	PM1	MM2
	PM4	MM4
	PM4	MM9
	PM7	
	PM9	MM5
7N rerun	PM8	
	PM9	
	PM10	MM6
	PM14	MM3
6N	PM26	MM3
	PM17	MM2
	PM10	MM2
5N	PM15	
	PM7	MM4
4N west	PM6	MM4
	PM4	MM3
	PM1	MM5
3N	PM11	MM5
	PM11	
	PM8	
	PM6	MM4
2N	PM2	MM12
	PM2	MM16
	PM2	MM28
	PM2	MM31
	PM1	MM10
1N	PM1	MM125
	PM1	MM5
	PM2	MM6

Line Designation	Location*	
IS	PM1	MM17
	PM1	MM8
	PM1	
	PM1	MM3
C	PM4	MM1
DE	PM7	MM4
E	PM8	MM1
FG	PM11	MM3
G	PM12	MM2
	PM12	MM6
H	PM14	MM6
	PM14	MM10
HI	PM15	MM5
I	PM16	MM7
	PM16	MM10
L	PM24	MM16
	PM25	MM3
	PM26	MM3
	PM26	MM8
	PM26	MM10
P	PM4	MM5
Q	PM7	MM2
	PM13	MM6
	PM13	MM9
	PM13	MM15
T	PM16	MM6
	PM17	MM3
	PM17	MM5
U	PM23	MM6
	PM20	MM6
V	PM25	MM4
	PM25	MM10
	PM26	MM5
	PM27	MM13
2W	PM12	MM3
	PM15	
3W	PM1	MM7
1N shadow	PM3	
2N shadow	PM4	MM3
	PM3	
4N shadow	PM2	MM8
	PM1	MM5
5N shadow	PM1	MM11
3S ext	PM7	MM3
	PM1	MM5
5S ext	PM3	MM6

* PM refers to Position Mark and MM to Minute Mark and are so indicated on the seismic lines and range-range data.